GENERAL ATOMIC DIVISION

GENERAL DYNAMICS CORPORATION

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EXPERIMENTAL INVESTIGATION OF THE FUNDAMENTAL MODES OF A COLLISIONLESS PLASMA

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INTRODUCTION

During the current period we have been making machine modifications and developing instruments necessary for the experiment as well as making measurements on the plasma properties. We have built the new probe manipulators necessary for the experiment, and have greatly reduced electromagnetic coupling between the probes with a shielding technique. The signal-to-noise ratio of the receiver has also been materially improved. A number of measurements on the geometry of the plasma and on the noise in the plasma have been made. These and other results are discussed in the following pages.

Probe Manipulators

We have redesigned the probe manipulators to improve them mechanically. The probes may now be radially retracted 3-1/2" and a transducer has been installed on this motion so that floating potential, saturation currents, and wave power may be plotted on the x-y recorder as a function of radius automatically. The probe may still be moved longitudinally the full length of the machine and this motion is also transduced. The new manipulators have been improved mechanically to eliminate binding and jamming troubles we have had previously with the longitudinal motion. The accuracy of the angular manipulator has also been greatly improved. These new manipulators have been installed on the machine and appear to perform satisfactorily.

Electromagnetic Shielding

A difficulty with our transmission experiments in the past has been the problem of sorting out plasma wave effects from direct electromagnetic coupling between probes. Since the wave lengths involved in the two effects are very different, it has always been possible to determine whether we were seeing plasma waves or electromagnetic coupling, but it is nevertheless difficult to measure the damping of plasma waves when the electromagnetic coupling is large. We have achieved a very large reduction in electromagnetic coupling by surrounding the plasma with a stainless steel tube which is designed as a waveguide beyond cutoff. We have tried tubes of various sizes from 3" to 6". For the 3" tube we obtain an attenuation of about 8 db/cm of separation which is satisfactory for our purposes. The tube is slotted almost full length so the probes can still be moved longitudinally.

Receiver Signal-to-Noise-Ratio

For our first transmission experiments we used a swept frequency transmitter and a wide band receiver which displayed the detected signal on an oscilloscope. It has become clear that this sort of system does not have sufficient sensitivity or signal-to-noise-ratio to observe the transmission of heavily damped waves. Since much of our interest is in the transmission and damping of waves that are heavily damped, we have had to devise a more sensitive detection scheme. We now use a transmitter set at a single rf frequency, and chopped at a few kilocycles. The receiver includes a sharp, high frequency filter, a string of broad band amplifiers, an r-f detector, a video amplifier, and a coherent detector operated at the transmitter chopping frequency. The rf bandwidth is thus a few hundred kilohertz and the video bandwidth of the coherent detector is a few hertz. This improves the signal-to-noise-ratio, and hence the usable sensitivity of the receiver by 40 or 50 db. We have not yet tried this system for waves near the cyclotron frequency but its application to a related experiment has enabled us to see transmission in a heavily damped region which was unobservable before, and we expect similar improvement in the electron cyclotron experiment. So far we are able to exploit this technique to maximum advantage only in the range 25 to 250 megacycles because we lack sufficient gain at higher frequencies. We are presently in the final stages of evaluating circuitry for increasing the gain in the 300 to 1000 megacycle range.

Plasma Parameters

We have made a series of measurements with Langmuir probes on the geometry and parameters of the plasma. In a typical case we have a radius of 7 mm, a length of 230 cm, a density of 5×10^8 electrons/cm^3, a temperature of 12 ± 3 ev, and a neutral density of 5×10^{11} molecules/cc (mostly H_2).

The density may be varied from about 1×10^8 to about 3×10^9 by varying the duoplasmatron arc current. Hence we are able to set the plasma frequency either far above or below the cyclotron frequency. The plasma density falls about a factor of 10 in the length of the machine because ions are migrating radially across the magnetic field and striking the shield. We think this diffusion is due to noise in the plasma, perhaps induced by the duoplasmatron. We would like to reduce this effect as it complicates the analysis of the wave experiment, although probably not too seriously.

Plasma Noise

We have made a series of measurements of noise in the plasma, as observed by a probe, in the range from 30 kilocycles to 200 megacycles. For certain adjustments of the machine (which we avoid for the transmission experiments), the noise is of the order of volts at sharply defined frequencies of a few kilocycles. Under the operating conditions we choose, the noise is of the order of millivolts in the kilocycle ranges, and microvolts in the megacycle ranges. The noise on the electrodes of the duoplasmatron is much larger, which makes us think that at least some of this noise has its origin in the arc. The noise does not exhibit a sharp structure in frequency to enable us to easily identify its origin. We expect to be able to do transmission experiments in the presence of this noise but we also expect to do some work to eliminate it if possible. Another source of interference for these experiments is background electromagnetic radiation. The sensitivity of our receiver is such that, even though the system is well-shielded, we readily pick up the signals of local television stations and FM stations. Since all of these signals are narrow band, we can choose frequencies at which the filter in the receiver rejects them. Hence they constitute a nuisance but not a serious difficulty.

Financial

Approximately $20,000 has been expended or committed on this project to date.